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CONE PENETROMETER TESTING AT GREGG RIVER MINE

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by

R. Whipple* and R.J. Kolada**

ABSTRACT

The cone penetrometer consists of a proving ring attached by a rod to a steel cone. The test is performed by pushing the assembly into the ground and recording the dial gauge reading. The reading is then converted into a pressure called the Cone Index. The test can be done quickly and easily, a definite advantage over other soil testing methods.

Cone indices can be correlated to California Bearing Ratio Test results. Thus, cone penetrometer tests can be used as a supplement or substitute to California Bearing Ratio Tests.

This paper describes cone penetrometer tests taken on mine haulage roads at the Gregg River Mine.

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ESSAI AU MOYEN D'UN PÉNÉTROMÈTRE À CÔNE À LA MINE GREGG RIVER

par

R. Whipple* et R.J. Kolada**

RÉSUMÉ

Le pénétromètre à cône est formé d'un anneau dynamométrique fixé à un cône d'acier au moyen d'une tige. L'essai de pénétration consiste à pousser le montage dans le sol et à faire la lecture du cadran indicateur. Ces informations sont ensuite converties en une pression appelée l'indice de résistance à la pointe. L'essai peut se faire rapidement et facilement, ce qui constitue un net avantage sur les autres méthodes d'essai des sols.

On peut faire une corrélation entre l'indice de résistance à la pointe et les résultats de l'essai d'indice portant californien. Par conséquent, les essais de pénétration peuvent servir à compléter ou à remplacer les essais d'indice portant californien.

Le présent rapport décrit les essais de pénétration effectués sur les routes de transport à la mine Gregg River.

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1.0 INTRODUCTION

The cone penetrometer was developed for soils testing. A cone with a base area of approximately 1.0 square inches is pushed vertically into the ground. A flexible steel proving ring with an attached dial gauge is read when the cone has penetrated approximately 1 inch. The main advantage is the speed with which the test can be done.

The cone penetrometer test is a method for measuring the resistance of soils to static or dynamic penetration of cones. In their book "Soil Mechanics For Off-Road Vehicles", Messrs. Karafiath and Novatzki mention the vide uses of the test in the soils engineering disciplines. For off-road applications penetrometer testing provides an indirect evaluation of soil conditions.

Thirty-six tests were performed at the Gregg River Mine. All of the cone penetrometer tests were done in a small area of LM2 Pit (an active mining area). The appoximate location was 15 metres out from a point about midway along the footwall. The spacing between sites was approximately 0.1 metres. The first set of twelve tests were done on the pit floor. The second set were performed after a layer of coal had been scraped away. Another group of tests were carried out in a tire track left by the rolling resistance vehicle.

2.0 TEST PROCEDURE

The test procedure used at the Gregg River Mine is summarized here:

1. The 250 lb. capacity proving ring was connected to the 18" penetrometer rod. The rod and ring were attached to a right angle cone with a base diameter of 28.7mm (1.13"),
2. An initial dial gauge reading was noted,
3. With a steady force, the penetrometer was pushed into the ground until the base of the cone point was level with the ground surface,
4. A final reading was recorded.

Following the field tests, calculations were performed to define the bearing capacity of the material. Using an electronic spreadsheet,

formulae were entered from the manufacturer's documentation. This information permits correlation of the net reading from the dial gauge to units of force.

As outlined in the manual (Soiltest, Inc.,Evanston,Illinois, "Operation and Service Instructions"), the base area should be 0.983 square inches. Allowing 2% for friction between the cone/soil interface allows the force values to be read directly as bearing pressures. The base diameter of the cone point was measured at 1.13 inches. This represents an area of 1.0029 square inches. Using the two percent friction factor increases the base area to 1.0229 square inches.

Dividing the force by the area of the base of the cone yields the unit pressure, also known as the cone index (CI). (Results have been tabulated in the attached appendix.)

3.0 TEST RESULTS

The average cone index for the first set of data is the lowest of the three groups (0.55 MegaPascals). This indicates that the surface layer of the pit floor does not carry much load, rather it transmits the force to underlying material. The standard deviation is a measure of dispersion. The calculated deviation was 0.16 MPa on the "undisturbed" pit floor. This dispersion may seem large but the particle size distribution (gradation) of the material is inhomogeneous after activities such as excavation and grading.

Removing the top 2 inches (0.05 m) caused an increase in the average cone index to 1.03 MPa. With the increased CI, the standard deviation increased to 0.22 MPa.

The final group of tests were performed in a tire track made by the rolling resistance vehicle. The cone index average is 0.87 MPa with a standard deviation of 0.15 MPa. It is possible the compaction of the surface layer by the wheel resulted in a slightly higher mean CI. The dispersion is lowest for this set of tests.

4.0 DISCUSSION OF TEST RESULTS

Two statistical analyses were performed. These tests and calculations are based on the assumption that the sample data represent a population with a normal distribution. Ideally one should collect a large number of random samples so the sample mean and variance could approach those of the population. It is however, unfeasible at this time to perform a sampling campaign of this magnitude. It is more important to obtain results which will aid in the correlation of rolling resistance to soil and roadway parameters. All of the formulae used in the analyses can be found in a text titled "Probability and Statistics for Engineers" by Messrs. I. Miller and J.E. Freund (Third Edition,Prentice-Hall Inc.,1985).

The first statistical test was to check for a significant difference between the population means of each set of results. To compare two means one must choose a "null hypothesis". It states that there is no significant difference. A z-statistic is calculated (see Miller & Freund p.219) and compared to a tabulated value, based on a decided significance level. In the case of this analysis where one is concerned about the presence of a difference, a two-tailed z-value is read from the table. If the calculated z-statistic lies outside a range specified by the tabulated, the "null hypothesis" is rejected. By dismissing the null hypothesis one accepts the alternative hypothesis; the means are different at the chosen level of significance. The significance level means that for each 100 comparisons made in exactly the same manner, five will be in error. At the 95% significance level, the mean cone indices are different. Therefore, the population means are different and each group of results is said to be from different populations.

It is nov apparent that the variations in the test conditions have affected the results. The average cone index on the "undisturbed" pit floor is not the same as that of a subsurface layer which is not the same as the mean cone index in a tire track.

The F-statistic (Miller and Freund,pp.237-240) was utilized to test for significant differences between the sample variances. The test is done by stating two hypotheses. Based on a comparison of the calculated F-ratio ($F=s_1^{-2}/s_2^{-2}$) to a tabulated F-statistic (for n_1 and n_2 degrees of

freedom at 95 percent probability), either the null or alternative hypothesis is accepted. The null hypothesis resulted for all comparisons. That is, no significant differences exist between the population variances.

The statistical tests of comparing variances has provided little information. No significant differences could mean the tests are being performed with adequate precision (similar, but high standard deviation). It is entirely possible that high dispersion could be masking inconsistencies in procedure.

Calculations have been done to determine how many tests are required to have a tolerance of 0.1 MPa for the average cone index. The number of required samples is a function of the confidence level, population standard deviation and error tolerance. Using the 95% confidence interval for variance, up to as many as fifty-seven samples would be necessary to meet a tolerance of plus/minus 0.1 MPa. If the tolerance is reduced to 0.05 MPa, a minimum of 39 samples, and as many as 225 may be required. These estimates are based on the data from Test Set #2. The sample variance for this group represents the worst case.

5.0 CONCLUSIONS

The cone penetrometer testing performed at the Gregg River Mine has been successful. The following results were obtained from thirty-six tests:

TEST CONDITION	MEAN CI	STD. DEVN
"Undistributed" pit floor	0.55 MPa	0.16 MPa
Layer 2" coal removed	1.03	0.22
Tire track	0.87	0.15.

Sufficient data were collected for a limited statistics analysis. It has been concluded that, based on the assumption of normally distributed data, the mean cone indices are from different populations. More importantly though, the different horizons of a pit floor probably have different load carrying capacities. In addition, the load capability of the pit floor is significantly affected by the passage of rubber-tyred vehicles.

Because there were not any significant differences in variances, one is unable to make any conclusions. Perhaps the large magnitude of dispersion is hiding procedural errors. It is very difficult to repeatedly

push the pole assembly into the ground with any precision. One could monitor testing methods to control standard deviation, but achieving this goal may not be worth the required effort because of substantial increases in time taken to do the tests.

To prove or disprove the assumption of normally distributed data thirty-nine to two hundred and twenty-five samples would have to be collected from a small area. Until such time as when the cone penetrometer is viewed as an indispensible test for correlating rolling resistance data, a large sampling campaign is not warranted. The speed with which tests can be done does give it a decided advantage over other methods, namely the California Bearing Ratio Test.

BIBLIOGRAPHY

1. ANONYMOUS, "Operation and Service Instructions" (for Proving Ring Penetrometer Model No. CN-970), Soiltest Inc., Evanston, Illinois, U.S.A.

2. Karafiath, L.L. and Nowatzki, E.A., "Soil Mechanics for Off-Road Vehicle Engineering", Trans-Tech Publications Series on Rock and Soil Mechanics, Vol. 2, No. 5, Clausthal, Germany, 1978.

3. Miller, I. and Freund, J.E., "Probability and Statistics for Engineers", Third Edition, Prentice-Hall Inc., Englewood Cliffs, N.J., 1985.

APPENDIX A

CONE PENETROMETER TEST RESULTS

EMR (CANMET) SURFACE MINING LAB
ROLLING RESISTANCE PROJECT
CONE PENETROMETER RESULTS

Client: Gregg River Resources Ltd. Date: May 27,1987
Location: Gregg River Mine LM2 PIT
Proving Ring: CN-970 Serial Number: 21690

INITIAL READING (divisions)	FINAL READING (divisions)	NET READING (divisions)	CONE INDEX (lb./sq.nch)	CONE INDEX (MPa)
TEST SET #1 done on LM2 Pit floor near FW				
26	241	215	70.8	0.488
27	239	212	69.9	0.482
27	226	199	65.8	0.454
30	186	156	52.3	0.360
26	227	201	66.4	0.458
26	267	241	79.0	0.545
26	307	281	91.6	0.632
27	199	172	57.3	0.395
27	283	256	83.7	0.577
26	468	442	142.3	0.981
31	325	294	95.7	0.660
27	271	244	80.0	0.551
	N = 12	AVERAGE=	79.56	0.549
		STD DEV=	23.60	0.163
TEST SET #2 top 2" (0.05m) of coal removed LM2 Pit				
26	416	390	125.9	0.868
27	645	618	205.6	1.363
27	340	313	105.8	0.701
26	460	434	145.4	0.963
26	434	408	136.9	0.907
26	541	515	171.9	1.139
26	611	585	194.8	1.291
26	496	470	157.2	1.042
26	327	301	101.8	0.675
27	446	419	140.5	0.931
27	596	569	189.6	1.256
27	561	534	178.1	1.180
	N = 12	AVERAGE=	154.5	1.026
		STD DEV=	34.24	0.225
TEST SET #3 done in tire track in LM2 Pit				
26	401	375	121.2	0.835
27	525	498	159.9	1.102
28	476	448	144.1	0.994
28	491	463	148.9	1.026
27	410	383	123.7	0.853
28	437	409	131.9	0.909
28	329	301	97.9	0.675
27	387	360	116.5	0.803
27	486	459	147.6	1.018
27	405	378	122.1	0.842
28	280	252	82.5	0.569
28	399	371	119.9	0.827
	N = 12	AVERAGE=	126.3	0.871
		STD DEV=	22.07	0.152